# CHAPTER 17

# HEADWALLS

17-1. General.

a. Purpose. The normal functions of a headwall or wingwall are to recess the inflow or outflow end of the culvert barrel into the fill slope, to improve entrance flow conditions, to anchor the pipe and prevent disjointing due to excessive pressures, to control erosion and scour resulting from excessive velocities and turbulences and to prevent adjacent soil from sloughing into the waterway opening. Many of these functions can be provided for by other means and headwalls should only be used in special cases such as limited space or poor soils highly susceptible to erosion or sloughing.

b. Scouring. Where headwalls are used, provisions for drainage should be made over the center of the headwall to prevent scouring along the sides of the walls.

c. Requirements for usage. Erosion protection such as riprap, or sacked concrete with a sand-cement ratio of 9:1, may be used around the culvert entrance when a headwall is not used. The decision as to whether or not a headwall is necessary depends on the expected flow conditions and embankment stability.

17-2. Entrances. The rounding or beveling of the entrance in almost any way will increase the culvert capacity for every design condition. These types of improvements provide a reduction in the loss of energy at the entrance for little or no additional cost. In design of headwalls some degree of entrance improvement should always be considered. Several preformed flared or warped sections are available to increase inlet hydraulic efficiencies.

17-3. Types of headwalls.

a. Height. Headwall and wingwall heights should be kept to the minimum that is consistent with hydraulic, geometric, and structural requirements. Assuming a structure is required, typical applications of straight headwalls and winged headwalls consist of the following types.

b. Straight headwalls. Straight headwalls are used for low to moderate approach velocity, light drift (small floating debris), broad or undefined approach channels, or small defined channels entering culverts with little change in alinement.

c. L headwalls. "L" headwalls are used for either gutter drainage or defined channels with low to moderate velocity where abrupt change of alinement is required at the culvert inlet.

d. Wing headwalls. Winged headwalls are used for channels with moderate velocity and medium drift (floating trash). Wings are best set flush with the edges of the culvert barrel, alined with respect to stream axis, and placed at a flare angle of 18 to 45 degrees.

17-4. Headwall construction. Headwalls are normally constructed of reinforced concrete or masonry and often include wingwalls and aprons. Drainage pipe and culvert manufacturers offer a variety of precast or preformed inlet and outlet sections to replace or simplify headwall construction.

17-5. Outlets and endwalls.

a. Undermining endwalls. Most culverts outfall into a waterway of relatively large cross section; only moderate tailwater is present, and except for local acceleration, if the culvert effluent freely drops, the downstream velocities gradually diminish. In such situations the primary problem is not one of hydraulics but is usually the protection of the outfall against undermining bottom scour, damaging lateral erosion, and perhaps degradation of the downstream channel. The presence of tailwater higher than the culvert crown will affect the culvert performance and may possibly require protection of the adjacent embankment against wave or eddy scour. In any event, a determination must be made about downstream control, its relative permanence, and tailwater conditions likely to result. Endwalls (outfall headwalls) and wingwalls will not be used unless justifiable as an integral part of outfall energy dissipators or erosion protection works.

b. Endwall protection. Failure of the system will take place if there is inadequate endwall protection. Normally the end sections may be damaged first, thus causing flow obstruction and progressive undercutting during high runoff periods which will result in washout of the structure. For corrugated metal (pipe or arch) culvert installations, reinforced pipe, and PVC pipe, use of prefabricated end sections may well prove desirable and economically feasible. When a culvert outfall projects from an embankment fill at a substantial height above natural ground, either a cantilevered free outfall pipe or a pipe downspout will probably be required. In either case the need for additional erosion protection requires consideration.

c. Energy dissipators. Various designs of energy dissipators, flared transitions and erosion protection for culvert outfalls are discussed in detail in other chapters of this manual. See paragraphs 20-1 through 20-7 and part four, chapter 14.

17-6. Structural stability. The proposed structure will be adequate to withstand soil and hydrostatic pressures and in areas of seasonal freezing the effects of frost action. The structure will be designed to preclude detrimental heave or lateral displacement as the result of frost action. The most satisfactory method of preventing such damage is to restrict frost penetration beneath and behind the wall to nonfrost-susceptible materials. Positive drainage behind the wall is also essential. Bedding requirements will be determined in accordance with procedures outlined in note 4, table 8-4.

17-7. Sloughing. The proposed structure will be large enough to preclude the partial or complete stoppage of the drain by sloughing of the adjacent soil. This can best be accomplished by a straight headwall or by wingwalls. Typical erosion problems result from uncontrolled local inflow around the endwalls. The recommended preventive for this type of failure is the construction of a berm behind the endwall (outfall headwall) to intercept local inflow and direct it properly to protected outlets such as field inlets and paved or sodded chutes that will conduct the water into the outfall channel. The proper use of solid sodding will often provide adequate headwall and channel protection.

17-8. Apron.

a. Protection. Paved aprons are probably the oldest and simplest form of culvert protection. Protection is provided to the local area covered by the apron and a portion of the kinetic energy of flow is reduced or converted to potential energy because of the hydraulic resistance provided by the apron.

b. Requirements. The necessity for an apron or stilling basin is determined largely by the soil characteristics of the adjacent open channel and by the anticipated maximum velocities and turbulence at the pipe outlet. Most culverts operate under free outfall conditions, i.e., controlling tailwater is absent, and the discharge possesses kinetic energy in excess of that naturally occurring in the waterway. This excess kinetic energy often must be dissipated to control damaging erosion. The extent to which protective works are required for energy dissipation depends on the amount of excess kinetic energy and the characteristics of the material in the outlet channel. The soil type will indicate the maximum permissible velocities for open channels. These velocities are given in part three table 10-1. The velocity may be regulated so far as it is feasible to vary the hydraulic gradient of the storm drain or outfall ditch. If excessive discharge velocities do occur, an apron of adequate design will be provided to reduce the velocities to permissible values. As an additional precaution, a cutoff wall will be provided to minimize the possibility of undermining the structure. Concrete aprons will be designed to preclude structural damage from differential movement caused by frost action during no-flow periods or by expansive subgrade soils.

c. Parameter calculations. Test results of recent studies for simple outlet transitions with the apron at the same elevation as the culvert invert are shown in figure 17-1. The maximum discharge

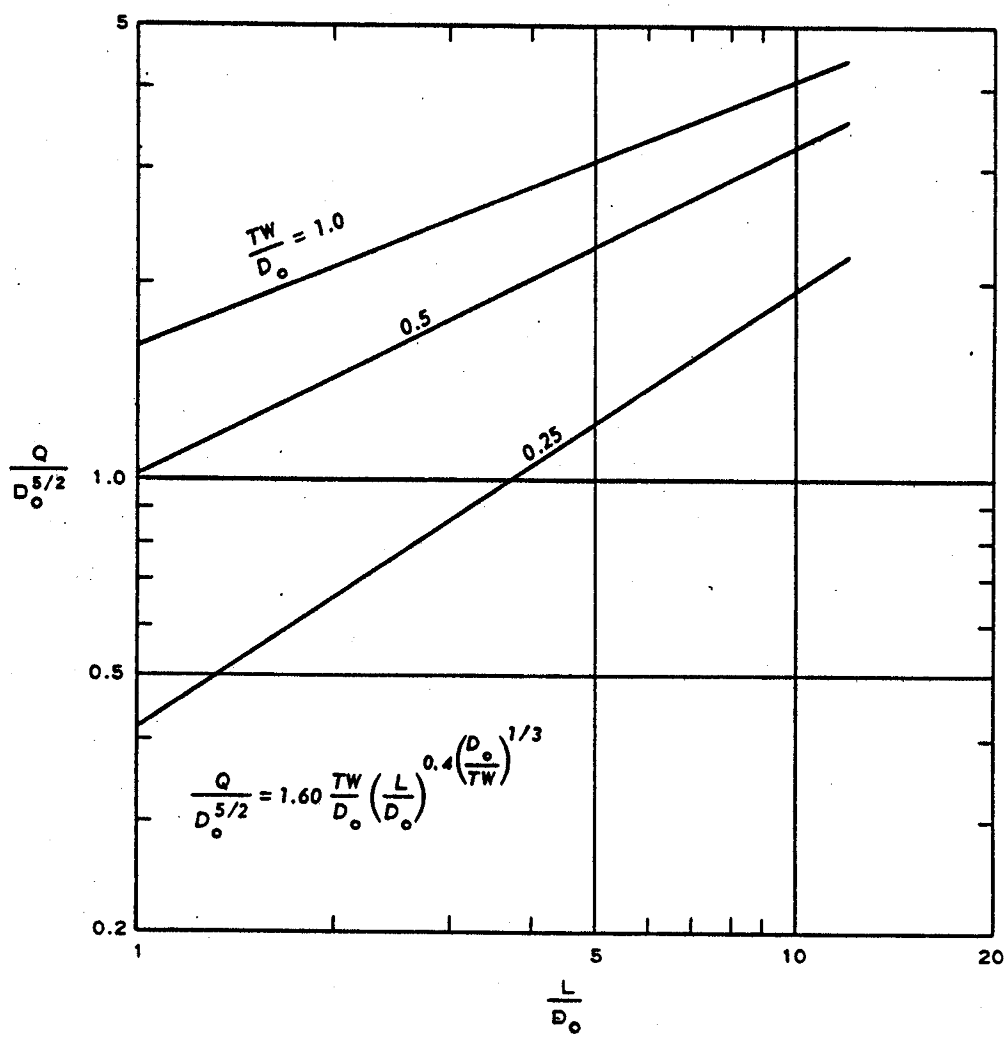


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FIGURE 17-1. MAXIMUM PERMISSIBLE DISCHARGE FOR VARIOUS LENGTHS OF FLARED OUTLET TRANSITION AND TAILWATERS parameter for a given culvert length of transition and tailwater can be calculated by the following equation:

$$\frac{Q}{D_o^{5/2}} = 1.60 \; \frac{TW}{D_o} \left(\frac{L}{D_o}\right)^{0.4(D_o/TW)^{1/3}}$$

where:

Q = Discharge, cfs
$D_o$ = Diameter of circular culvert, feet
TW = Tailwater depth above invert of culvert outlet, feet
L = Length of apron, feet

Similarly, the length of transition for a given situation can be selected by the interrelations shown in figure 17-2, which is calculated by the following equation:

$$\frac{L}{D_o} = 0.30\left(\frac{D_o}{TW}\right)^2 \left(\frac{Q}{D_o^{5/2}}\right)^{2.5\,(TW/D_o)^{1/3}}$$

Variables show that this type of protection is satisfactory only for limited values of $Q/Do^{5/2}$ and $TW/D_o$. Arbitrary extent of scour depth equal to or less than $0.5D_o$ was used to classify satisfactory conditions.

d. Tailwater elevations. Figure 17-3 indicates that recessing the apron and providing an end sill at the downstream end did not significantly improve energy dissipation or increase the applicable maximum value of the discharge parameter, $Q/D_o^{5/2}$. The limiting values of the discharge parameter for various outlet transitions and tailwater elevations are listed in table 17-1.

e. Endwall elevations. Numerous endwall failures have occurred as a result of improper consideration of the relative elevation of the apron and outfall channel. If practicable, the apron elevation will be selected to insure that sufficient depth of backwater occurs over the apron during design flow conditions to prevent undesirable erosion, otherwise positive erosion protection measures will be required. Newly excavated channels erode slightly during the aging process, and proper allowance for this action must be included in establishing the apron elevation.

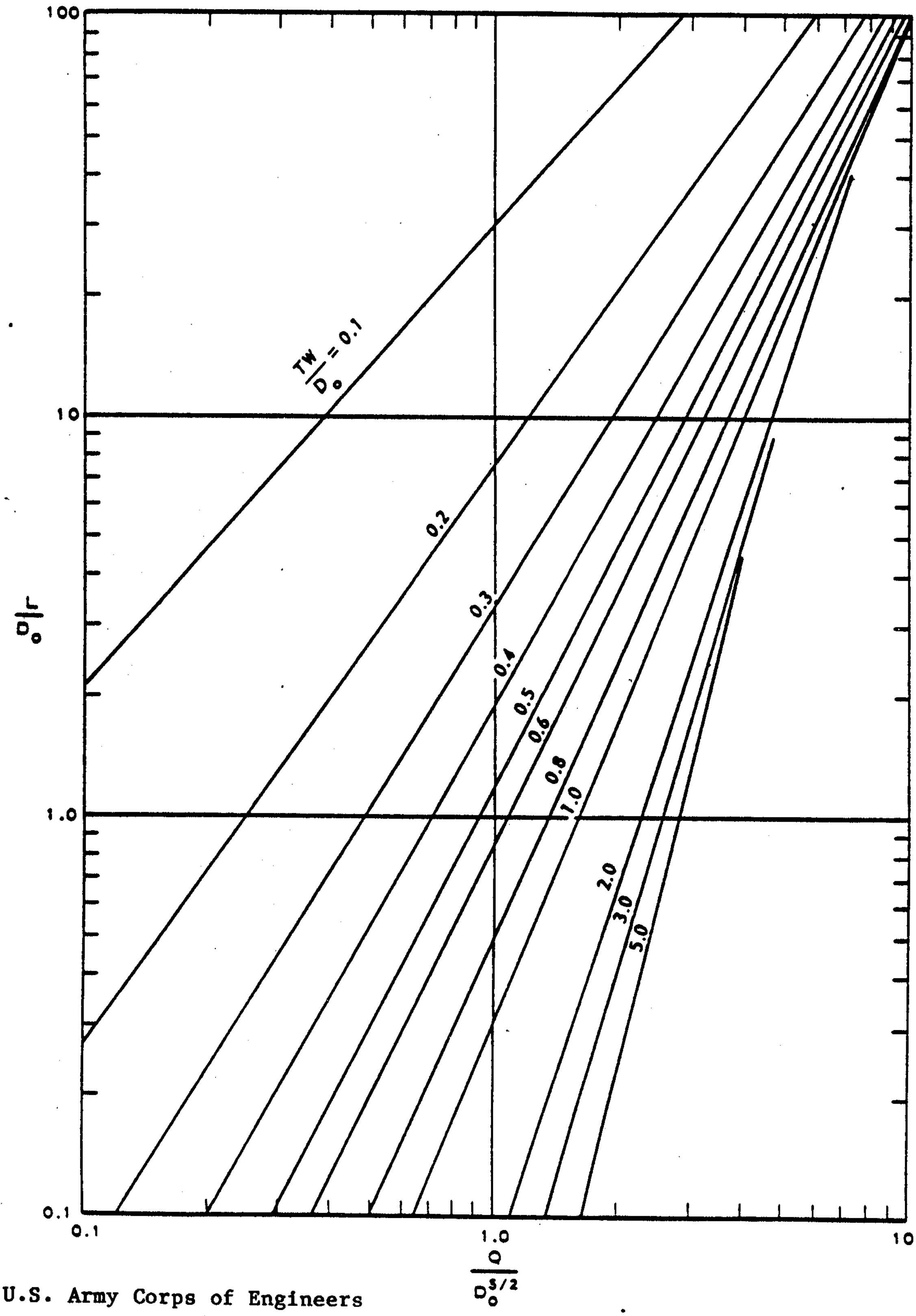


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FIGURE 17-2. LENGTH OF FLARED OUTLET TRANSITION RELATIVE TO DISCHARGE, TAILWATER, AND CONDUIT SIZE

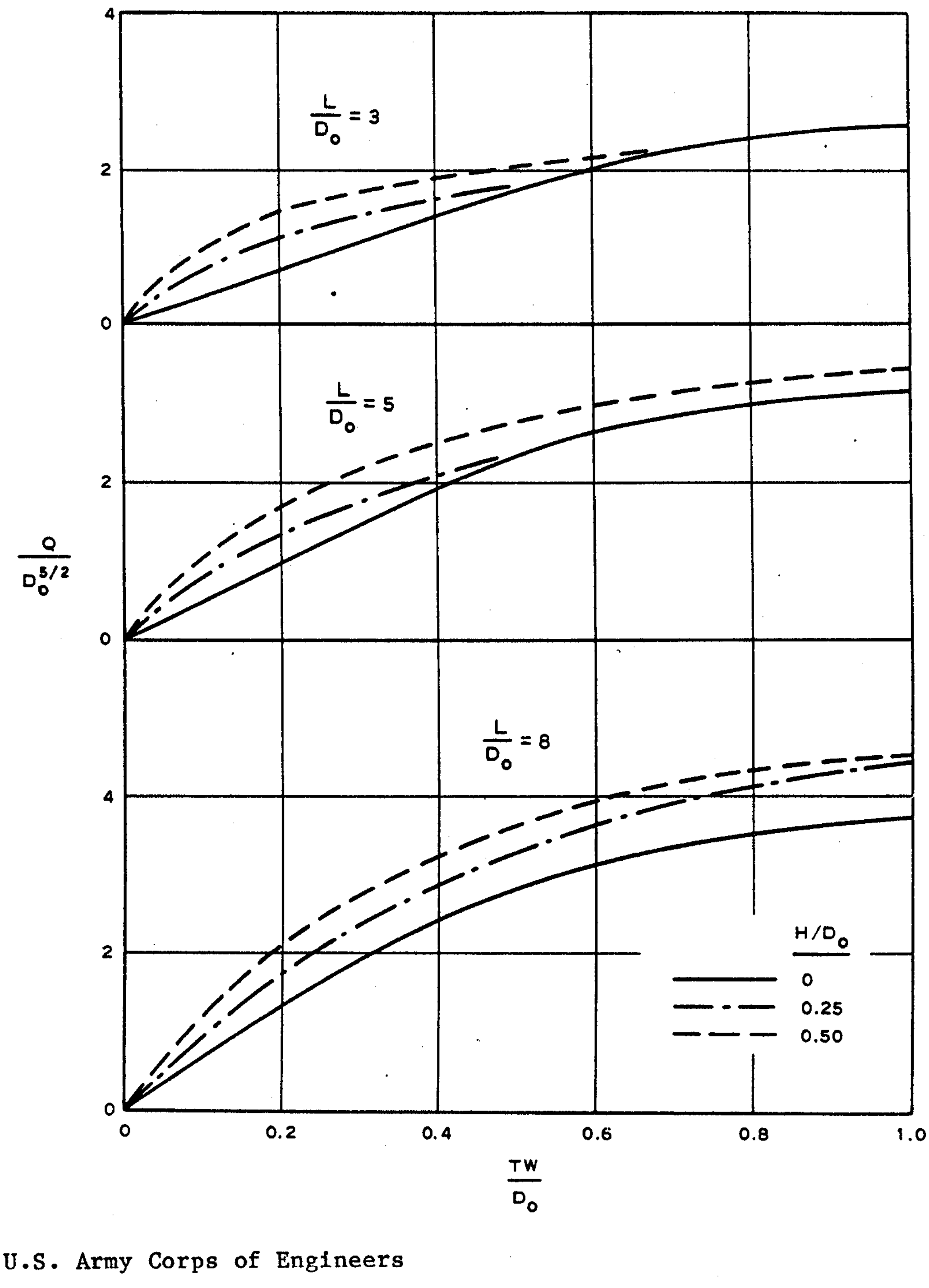


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FIGURE 17-3. RELATIVE EFFECTS OF RECESSED APRON AND END SILL ON PERMISSIBLE DISCHARGE

Table 17-1. Limiting Values of $Q/D_o^{5/2}$

| $L/D_o$ | $H/D_o$ | $TW/D_o$ | $Q/D_o^{5/2}$ |
|---|---|---|---|
| 3 | 0 | 0.25 | 0.88 |
| 3 | 0 | 0.50 | 1.78 |
| 3 | 0 | 1.00 | 2.56 |
| 3 | 0.25 | 0.25 | 1.28 |
| 3 | 0.25 | 0.50 | 1.78 |
| 3 | 0.25 | 1.00 | 2.56 |
| 3 | 0.50 | 0.25 | 1.58 |
| 3 | 0.50 | 0.50 | 2.00 |
| 3 | 0.50 | 1.00 | 2.56 |
| 5 | 0 | 0.25 | 1.20 |
| 5 | 0 | 0.50 | 2.40 |
| 5 | 0 | 1.00 | 3.20 |
| 5 | 0.25 | 0.25 | 1.58 |
| 5 | 0.25 | 0.50 | 2.78 |
| 5 | 0.25 | 1.00 | 3.47 |
| 5 | 0.50 | 0.25 | 1.47 |
| 5 | 0.50 | 0.50 | 2.77 |
| 5 | 0.50 | 1.00 | 3.46 |
| 8 | 0 | 0.25 | 1.68 |
| 8 | 0 | 0.50 | 2.40 |
| 8 | 0 | 1.00 | 3.75 |
| 8 | 0.25 | 0.25 | 2.17 |
| 8 | 0.25 | 0.50 | 3.36 |
| 8 | 0.25 | 1.00 | 4.44 |
| 8 | 0.50 | 0.25 | 2.46 |
| 8 | 0.50 | 0.50 | 3.65 |
| 8 | 0.50 | 1.00 | 4.55 |

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